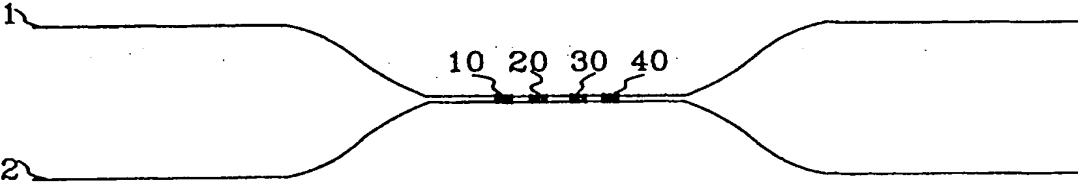


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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>H04J 14/02, H04Q 11/00, G02F 1/313, G02B 6/12</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 99/66664</b> <b>(43) International Publication Date:</b> 23 December 1999 (23.12.99)
<b>(21) International Application Number:</b> PCT/SE99/01054 <b>(22) International Filing Date:</b> 14 June 1999 (14.06.99) <b>(30) Priority Data:</b> 9802168-6      17 June 1998 (17.06.98)      SE <b>(71) Applicant:</b> TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE). <b>(72) Inventor:</b> GUSTAVSSON, Mats; Fatburs Brunnsgata 21, S-118 28 Stockholm (SE). <b>(74) Agent:</b> ERICSSON COMPONENTS AB; Dept. for Intellectual Property Rights, Kista, S-164 81 Stockholm (SE).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
<b>(54) Title:</b> METHOD AND MULTI-WAVELENGTH SELECTIVE SWITCH FOR SWITCHING AND REDIRECTION OF OPTICAL WAVELENGTHS		
		
<b>(57) Abstract</b> <p>The present invention concerns a multi-wavelength selective switch in the form of a directional coupler structure. The directional coupler structure comprises two waveguides, wherein the waveguides arranged exhibit different effective diffractive index. The waveguides in one section are arranged in the proximity of each other, such that an optical field in the first waveguide can overlap a second waveguide and vice versa and that in said section at least two gratings are arranged for co-directional coupling. Said gratings are arranged isolated from each other. The invention further comprises a method for switching of wavelength channels through the use of said multi-wavelength selective switch.</p>		

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**METHOD AND MULTI-WAVELENGTH SELECTIVE SWITCH FOR SWITCHING AND REDIRECTION OF OPTICAL WAVELENGTHS****FIELD OF THE INVENTION**

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The present invention relates to an optical multi-wavelength selective device, more precisely a multi-wavelength selective switch for rerouting and switching of wavelengths in and optical network, in which each wavelength may be separately rerouted. The invention also comprises a method for rerouting and switching or  
10 add/drop multiplexing of wavelengths in an optical network.

**BACKGROUND OF THE INVENTION**

In order to further increase the capacity on existing optical networks a number of  
15 methods are known. One means is to use so called wavelength division multiplexing (WDM) technique in order to improve the degree of utilization of the available bandwidth. In order to increase the network flexibility, devices able to reroute traffic in the optical network are necessary. Such devices for rerouting of the traffic are also suitable in order to utilize the network as efficiently as possible, and in case of network  
20 interrupts.

In "Wavelength Division Multiplexer with Photoinduced Bragg Gratings Fabricated in a Planar Lightwave Circuit Type Asymmetric Mach Zehnder Interferometer on Si" Y. Hibino et.al., IEEE Photonics Technology Letters, Vol. 8, No.1, January 1996 an  
25 optical element is described in which Bragg grating and a phase control element is used in a Mach Zehnder interferometer. The considered applications are wavelength division multiplexing and wavelength division de-multiplexing.

The above described device can however not be used as a multi-wavelength selective  
30 switch. If the described device is to be used for add/drop of several channels, as many

devices are needed as the number of handled add/drop pairs. This type of device is comparatively hard to reconfigure, i.e. it is a non-adaptable device.

In K.W. Cheung, D. A. Smith, J.K. Baran, J.J. Johnson: "Wavelength-selective circuit and packet switching using acousto-optic tunable filters" Globecom'90, pp 1541-1547, 1990, a manner is described of solving multi-wavelength selective rerouting of wavelength channels separate and independently of each other based on opto-acoustic switches. This type of rerouting typically uses a number of micro-seconds, which may be a problem in high speed transmissions.

In R.C. Alferness, L.L. Buhl, U. Koren, B.I. Miller, M. Young, T.L. Koch. "Broadly tunable InGaAsP/InP buried rib waveguide vertical coupler filter", Techn. Dig. Integrated Photonics Research, post-deadline paper, pp. 33-36, 1991 a tunable wavelength selective grating-assisted directional coupler comprising two waveguides having different effective refractive indexes and a grating described. This directional coupler can couple a wavelength from the first waveguide to the second waveguide.

The problem present in the know technique as regards multi-wavelength selective switches and re-directional devices is they this demand very big and complicated structures or more components, which results in big power losses and high costs, or in that they can not be used in connection with high speed transmissions.

#### SUMMARY OF THE INVENTION

In order to increase the capacity in an optical transmission system several know methods may be used. In wavelength division multiplexing the transmission channels are multiplexed and de-multiplexed on different carrier wavelengths to respectively from an information flow. Said multiplexing and de-multiplexing demands optical multi-wavelength selective devices. It may also be desirable to change the transmission route through the optical net for certain wavelength channels. For this purpose

components are needed having multi-wavelength selective performance characteristics such as a multi-wavelength selective switch.

5 A known problem related to multi-wavelength selective switches may be that these contribute to big power losses.

Another problem is that all by us known multi-wavelength selective switches exhibit a relatively complicated structure or a great number of components.

10 Another problem is that known multi-wavelength selective switches are relatively expensive to manufacture depending on said complicated structures or the number of components comprised.

15 Yet a problem is that certain known multi-wavelength selective switches exhibit relatively slow switching speeds, typically a number of microseconds.

The present invention approaches the said problem through a multi-wavelength selective switch in the form of a directional coupler structure comprising two waveguides arranged having different effective refractive index. The waveguides are at  
20 one section arranged in the proximity of each other, such that an optical field in each of the waveguides may overlap the other wherein at least one grating is arranged for co-directional coupling.

In a method according to the invention for switching and re-direction of optical  
25 wavelengths in an optical network one branch in a directional coupler structure comprising optical wavelengths is excited. The optical wavelengths are thereafter transmitted through said branch to the directional coupler structure. The optical wavelengths are thereafter transmitted through a section where the waveguides are arranged in the proximity of each other whereby none or at least one wavelength is  
30 influenced by at least one in this section arranged grating for co-directional coupling and is coupled to the other waveguide.

In a second embodiment according to the invention at least one wavelength selective amplifier is comprised in at least one branch of the directional coupler structure, e.g. in the form of a distributed-Brag-reflector-amplifier.

5

The object of the present invention is to obtain a multi-wavelength selective switch, the structure of which is so simple and compact as possible, such that the manufacturing thereby may be reduced compared to the available technique, and in which the switching speed still is relatively high.

10

A advantage of the present invention is that the power losses relatively seen may be kept low.

15

A further advantage of the present invention is that its remaining performance characteristics such as crosstalk and the like may be improved compared to know technique.

Still a further advantage of the present invention is that signal splitting only is performed when absolutely necessary.

20

The invention will now be described further using the preferred embodiments and with reference to the appended drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

25

Figure 1 shows an embodiment of a multi-wavelength selective switch according to the invention.

Figure 2 shows another embodiment of a multi-wavelength selective switch according to the invention.

30

PREFERRED EMBODIMENTS OF THE INVENTION

- 5 A multi-wavelength selective switch in the form of a directional coupler structure comprising two waveguides 1 and 2 and four gratings for co-directional coupling 10, 20, 30, and 40 is shown in figure 1. Said waveguides 1 and 2 are each arranged having different effective refractive indexes, i.e. the propagation speed of light is different in the two waveguides. In on section these waveguides 1 and 2 are arranged in the
- 10 proximity of each other such that an optical field from each of the waveguides may overlap the other. On each side of this section there are two branches of the waveguides. In the section in which the waveguides are arranged in the proximity of each other, four gratings are arranged for co-directional coupling 10, 20, 30, and 40. Said section is called a grating section. These gratings 10, 20, 30, and 40 may,
- 15 depending on their character as to repetivity and length, bring about that certain wavelength may be coupled from a first waveguide to a second waveguide. The gratings may be looked upon as some kind of a phase matching device, which allows certain wavelengths to be coupled from one waveguide exhibiting a first effective refraction index to a second waveguide exhibiting a second effective refraction index.
- 20 In phase matching one wavelength is coupled from one waveguide to another, and this corresponds thus to a cross coupling state for this wavelength. In phase mismatch no wavelengths are coupled between the waveguides and this thus corresponds to a bar coupler state for these wavelengths. The gratings 10, 20, 30, and 40 are arranged in said section such that the phase matching conditions may be separately influence for
- 25 each section, i. e. some type of isolation is present between the gratings 10, 20, 30, and 40 such that they as far as possible do not influence each other. A control signal for one grating section should only influence that one and none of the other grating sections.
- 30 Suppose that waveguide 1 is excited with an optical signal comprising four different wavelengths  $\lambda_1$ ,  $\lambda_2$ ,  $\lambda_3$ , and  $\lambda_4$ . These wavelengths will be transmitted through said

waveguide 1 and arrive at the section in which the waveguides have been arranged in the proximity of each other, i.e. at the different grating sections.

In the case that the waveguides 1 and 2 exhibit the same effective refractive index and the gratings for co-directional coupling 10, 20, 30, and 40 are not present, the power of the different wavelengths may be divided up essentially alike in the two waveguides.

In the present invention the different waveguides 1 and 2 exhibit different effective refractive indexes, which implies that the different wavelengths in the optical signal, in absence of any type of phase matching device, will not, or only to a very small extent be coupled from one waveguide to another. The gratings for co-directional coupling 10, 20, 30, and 40, which constitute phase matching devices are so constituted as to each control a certain wavelength.

The gratings 10, 20, 30, and 40 may be controlled using an electrical signal, which implies that a grating which in an un-controlled state will influence a certain wavelength, will influence another wavelength in a controlled state. Through this mechanism in the gratings for co-directional coupling each and every one of the excited wavelengths  $\lambda_1$ ,  $\lambda_2$ ,  $\lambda_3$ , and  $\lambda_4$  may be influenced independently of the other. The degree of phase match may be controlled using this electrical signal. In a so called broadcast state, the optical signal is distributed evenly between the two waveguides for a given wavelength. Preferably, each grating section is so designed, that it in at least one state, which is controlled by the grating section control signal, is phase mismatched for all wavelengths in the incoming signal, i.e. none of the incoming wavelengths are coupled from its incoming waveguide.

In the case described above where four wavelengths  $\lambda_1$ ,  $\lambda_2$ ,  $\lambda_3$ , and  $\lambda_4$  are present in the section where the waveguides are coupled to each other and which also comprises said grating, a certain wavelength may by application of a suitable current for each of the gratings be directed to any of the branches which exits said section. Each wavelength which is coupled into the waveguide 1 may be coupled out into the waveguide 1 and/or 2.



In figure 2 another embodiment of the multi-wavelength selective switch according to the invention is seen. The multi-wavelength selective switch comprises in this embodiment a directional coupler structure in the form of two waveguides 1 and 2 and  
5 four gratings for co-directional coupling 10, 20, 30, and 40 and eight wavelength selective optical amplifiers 50, 60, 70, 80. Said two waveguides, 1 and 2, are each arranged exhibiting different effective refractive indexes, i.e. the propagation speed of light is different in the two waveguides. In on section these waveguides, 1 and 2, are arranged in the proximity of each other, such that an optical field from each of the  
10 waveguides may overlap the other. On each side of this section there are two branches of the waveguides. In the section, in which the waveguides are arranged in the proximity of each other, four gratings are arranged for co-directional coupling 10, 20, 30, and 40. Said section is called a grating section. These gratings 10, 20, 30, and 40 may, depending on their character as to repetivity and length, bring about that certain  
15 wavelength may be coupled from a first waveguide to a second waveguide.

The gratings 10, 20, 30, and 40 are arranged in said section such that the phase matching conditions may be separately influence for each section, i. e. some type of isolation is present between the gratings 10, 20, 30, and 40, such that they as far as  
20 possible do not influence each other. A control signal for one grating section should only influence that one and none of the other grating sections.

In this embodiment wavelength selective optical amplifiers 50, 60, 70, 80 have been arranged in the branches on one side of the section, where the waveguides are in  
25 contact with each other, in order to differentially amplify the wavelength division multiplexed signals. In the broadcasting state the optical signal is distributed between the incoming waveguides, which implies that the intensity of light in each waveguide may be reduced to half the intensity when the signal is evenly distributed between the two waveguides.

This may be compensated by introducing a number, preferably the same number as the number of wavelengths, of wavelength selective optical amplifiers, such as current controlled distributed Bragg-reflector (DBR) amplifiers or quarter-wavelength chirping DBF amplifiers in the branches neighbouring to the section where the guides are in the proximity of each other. These amplifiers may be used for compensating the differences in signal strength for different wavelengths.

Every branch in this embodiment comprises as many wavelength selective optical amplifiers 50, 60, 70, 80 as the number of gratings for co-directional coupling 10, 20, 30, and 40 in the section in which the waveguides are arranged in the proximity of each other. In each branch the wavelength division multiplexed signals may be amplified differentially. This may be of importance in case a wavelength has been divided between the two waveguides and thus has decreased its intensity.

The wavelength selective optical amplifiers and the gratings for co-directional coupling may be manufactured according to methods well known to a man skilled in the art and thus hardly needs to be described further.

The present multi-wavelength selective switch may be manufactured as monolithic integrated optical components in any dielectric material, e.g. the system InGeAsP/InP.

The invention is naturally not limited to the above described and the embodiments shown on the drawings, but can be modified within the scope of the appended claims.

### Claims

1. A multi-wavelength selective switch for switching and redirection of optical wavelengths, characterized in that the switch is arranged in the form of a directional  
5 coupler structure comprising two waveguides, wherein the waveguides arranged exhibit different effective diffractive index, that the waveguides in one section are arranged in the proximity of each other, such that an optical field in the first waveguide can overlap a second waveguide and vice versa and that in said section at least two gratings are arranged for co-directional coupling, wherein said gratings are  
10 arranged isolated from each other.
2. A multi-wavelength selective switch according to claim 1, characterized in that all gratings are arranged having the same grating repetitivity.
- 15 3. A multi-wavelength selective switch according to claim 1, characterized in that at least one grating is arranged having a grating repetitivity which differs from the repetitivity of the other gratings.
4. A multi-wavelength selective switch according to claim 2 or 3, characterized in that  
20 at least in one branch of the directional coupler structure at least one wavelength selective optical amplifier is arranged.
5. A multi-wavelength selective switch according to claim 4, characterized in that the wavelength selective optical amplifier is a current-controlled distributed-Bragg-  
25 reflector (DBR) amplifier.
6. A multi-wavelength selective switch according to claim 5, characterized in that it is manufactured from a dielectric material.

7. A multi-wavelength selective switch according to claim 6, characterized in that it is manufactured from a semiconductor system, comprising element from the groups III-V of the periodic tables.

5 8. A multi-wavelength selective switch according to claim 7, characterized in that the grating for co-directional coupling may be influenced by an electrical signal.

9. Method for switching and re-direction of optical wavelengths in an optical network characterized in that

- 10 - the optical wavelengths are coupled into one branch of a directional coupler structure,  
- the optical wavelengths are transmitted through said branch to the directional coupler structure,  
- the optical wavelengths are transmitted through a section wherein the waveguides are  
15 arranged in the proximity of each other whereby none or at least one wavelength is influenced by at least one in said section arranged grating for co-directional coupling and is coupled to another waveguide.

10. Method according to claim 10, characterized in that in at least one branch of the  
20 directional coupler structure at least one wavelength is amplified by a wavelength selective amplifier.

11. Method according to claim 9 or 10, characterized in that the grating for co-directional coupling and the wavelength selective optical amplifier is influenced by an  
25 electrical signal.

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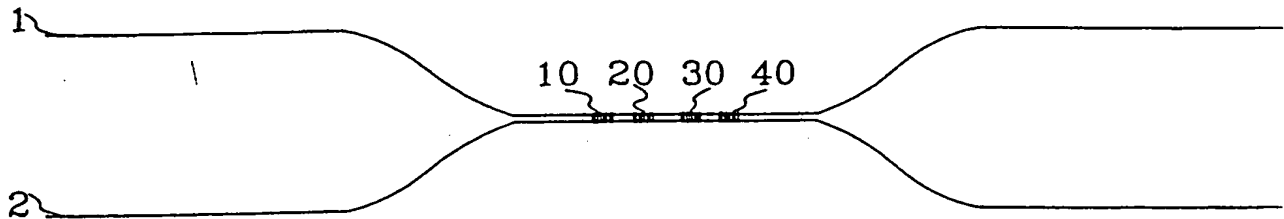


Fig. 1

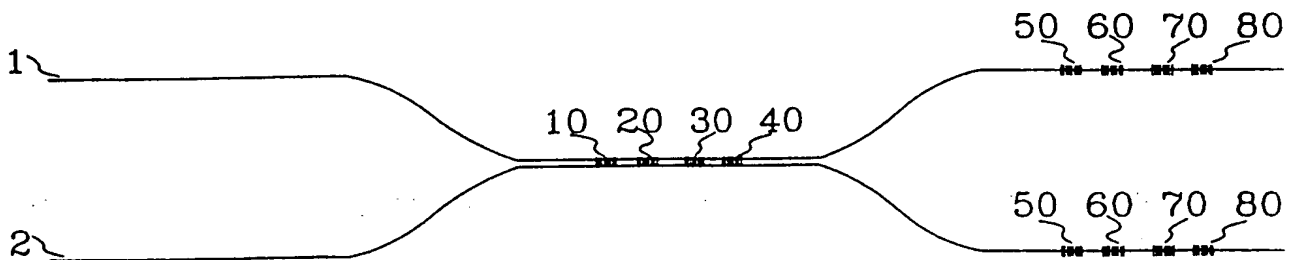


Fig. 2

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 99/01054

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04J 14/02, H04Q 11/00, G02F 1/313, G02B 6/12

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## B. FIELDS SEARCHED

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5416866 A (OLOF G. SAHLEN), 16 May 1995 (16.05.95), column 6, line 9 - line 54, figures 4, 5, claim 12 --	1,3,4,9-11
X	WO 9715851 (ARROYO OPTICS INC.), 1 May 1997 (01.05.97), page 13, line 3 - line 21, figure 9 --	1,3,9,11
X	EP 0778479 A2 (KOKUSAI DENSHIN DENWA KABUSHIKI KAISHA), 11 June 1997 (11.06.97), column 9, line 3 - column 12, line 14, figures 8,9 --	1,3,9,11
X	US 5502783 A (CHI WU), 26 March 1996 (26.03.96), column 5, line 20 - column 6, line 17, figures 3,4 --	9,11

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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26 November 1999

Name and mailing address of the ISA:

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Date of mailing of the international search report

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5710849 A (LITTLE ET AL), 20 January 1998 (20.01.98), abstract  --	9
A	EP 0475016 A2 (HITACHI, LTD), 18 March 1992 (18.03.92), column 3, line 37 - column 4, line 28, figures 1,3  -----	1-11

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02/11/99

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